India's Nascent Space Program

Thumba, Kerala, India. Scores of kilometers above the palm trees of India's 2-year-old rocket base at Thumba, the electrojet wanders. This earth-circling current, which varies in intensity and sometimes inexplicably reverses direction, is associated with the magnetic equator, which makes one of its few landfalls across southern India.

The electrojet is a main scientific target of India's new space program. The reasons for this choice are clear. The magnetic equator passes across few regions which would provide accessible sites for a rocket base from which a long series of rockets—covering perhaps a whole solar-activity cycle of 11 years—could be launched into the electrojet. The straight white beach at Thumba, a former fishing village northwest of Trivandrum, the capital of the state of Kerala, is such a site.

Before and during the International Geophysical Year of 1957–58, American scientists, among them L. J. Cahill of the University of New Hampshire, fired rockets into the electrojet. Indian scientists noted, however, that the instruments of these early experiments were crude as compared to those of only a decade later. When satellites became available, many of the Americans moved on to study other geophysical phenomena.

Indian scientists had already begun to investigate the geophysics of areas close to the magnetic equator through notable ground-based and balloon-borne studies of cosmic rays. At the Physical Research Laboratory of Ahmedabad in Gujarat, which has become the scientific center of the Indian space program, Vikram Sarabhai (now head of the Indian space program) and others concentrated on studies of the time-variation of cosmic-ray flux. At the Tata Institute of Fundamental Research, scientists examined balloon-borne emulsions to determine the composition of the primary cosmic rays hitting the top of the atmosphere, and from ground-based studies of secondary cosmic rays obtained information about the nuclear interactions between the incident cosmic rays and particles in the atmosphere.

Meteorological and ionospheric rocket studies were planned for the International Indian Ocean Expedition, which ends in 1965, and for the International Years of the Quiet Sun, 1964–65. The wind patterns of the monsoons in the Indian Ocean merit close study, it is thought, not only because they give striking evidence of interactions between the ocean and the atmosphere but also because of the possible influence of the sun's particulate radiation on the earth's weather.

To begin a program of measuring the movements of the neutral and ionized atmosphere in the region of the electrojet, India needed and got a great deal of help from abroad. The help included both scientific advice and equipment.

Here at Thumba, the U.S. National Aeronautics and Space Administration provided much tracking and telemetry equipment (including a $2-million Doppler radar trailer) and a launcher for Nike-Apache sounding rockets. In firings since 21 November 1963, the Nikes have been used to release sodium vapor in the ionosphere, or, because they have nonmetal nose cones, to carry magnetometers and ion counters through the electrojet.

From France has come a platform to launch two-stage Centaure rockets, which release clouds of sodium and other materials at high altitudes so that the action of ionospheric winds can be studied. In this program, Jean Blamont and his colleagues of the French space agency Centre National d'Etudes Spatiales (CNES) collaborate with the United States and other countries. France has also been supplying the Centaure rockets, but now India has begun making the frames, propellant and electronic instrumentation of these missiles under license and expects to fire the first Indian-made Centaure in the spring of 1966.

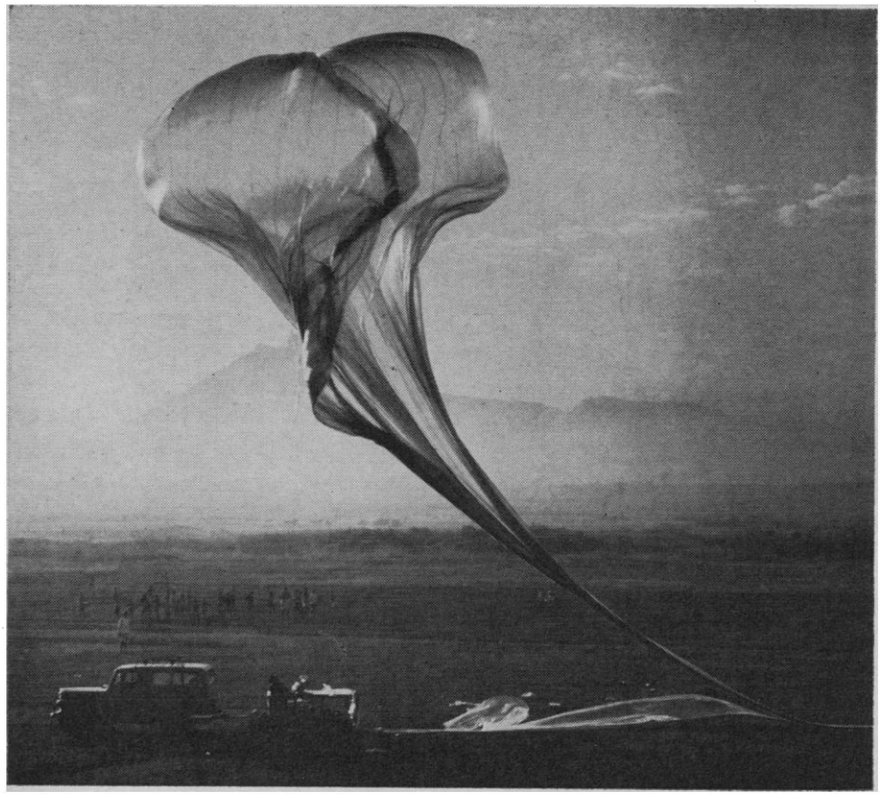
The Soviet Hydrometeorological Services have supplied a shaking-table for pre-flight tests, a range-survey helicopter, and a Minsk digital computer. The computer performs an average of 5000 to 6000 operations per second and prints out data at the rate of 1200 lines per minute.

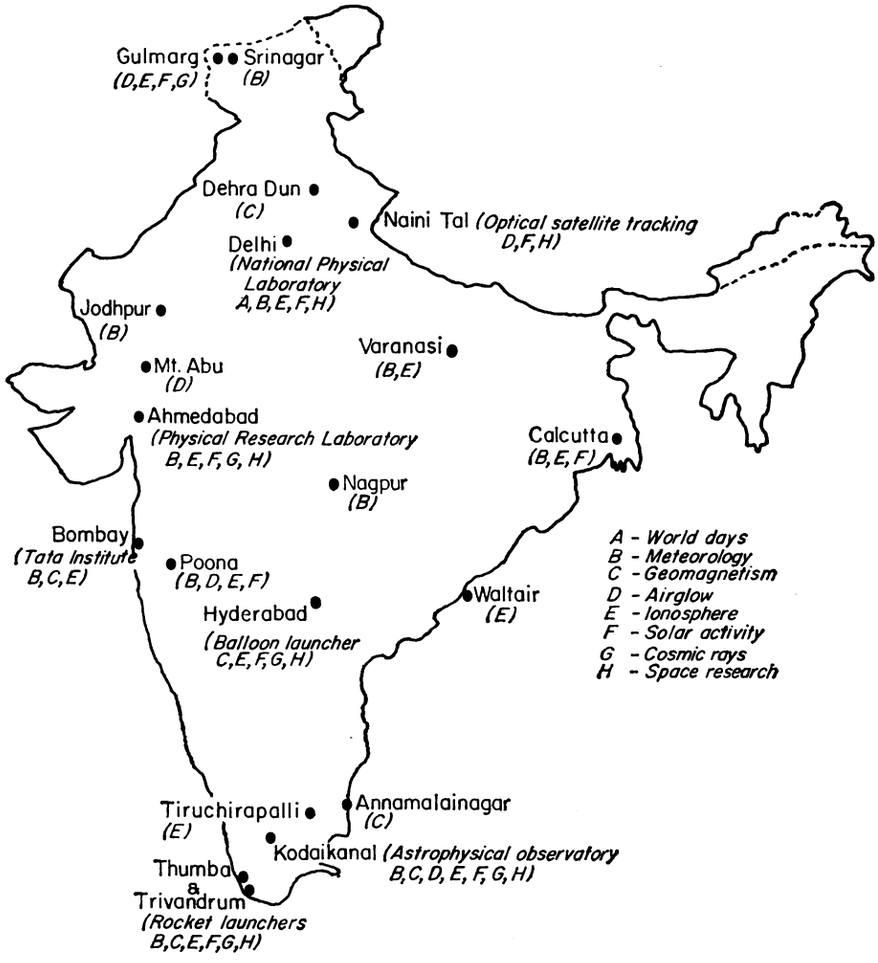
Up to now there has not been much collaboration with Britain, except on the Tata Institute's programs of cosmic-ray research. But sources in both India and Britain say they hope for greater collaboration soon—possibly to include firings of the British weather rocket Skua.

Besides such heavy capital assistance (usually without transfer of funds) there are other examples of India's dependence on cooperation with countries overseas in launching her small program of geophysics research. Most of the magnetometer and vapor payloads fired so far have been assembled outside India. The Judi-Dart meteorological rockets fired from Thumba and their chaff payloads are purchased in the United States. There is talk of getting American assistance to establish, at the Physical Research Laboratory in Ahmedabad, a dish antenna to read out data from the Alouette series of U.S.–Canadian satellites which are making soundings at the top of the ionosphere. It is hoped that, before the end of the year, a rocket will launch from Thumba a radio-frequency mass spectrometer of Soviet design. G. S. Gokhale of the Tata Institute and S. M. Poloskov of the Soviet Hydrometeorological Services are collaborating on the project. At Naini Tal in the foothills of the Himalayas, one of the many cameras of the worldwide network of the Smithsonian Astrophysical Observatory continues to make visual observations of satellites. Signals from the U.S. Naval Research Laboratory's solar radiation satellite are regularly received at Ahmedabad, and three Indian laboratories are monitoring the S-66 satellite launched 10 October 1964. With funds from the U.N. Special Fund, the Physical Research Laboratory is setting up a satellite communications antenna at Ahmedabad.

The Indian program is becoming less derivative, however. An important sign

The author, Victor K. McElheny, is European correspondent for *Science*. He will report frequently on important scientific installations and developments. Mr. McElheny has been a science news reporter for the Charlotte *Observer*, a Nieman fellow at Harvard, and recently was associated with the Swedish-American News Bureau in Stockholm. His address is Flat 3, 18 Kensington Court Place, London W.8, England. Telephone: Western 5360.





(Top) Balloon launching at the Newali Airfield, Kalyan, is under the direction of the Tata Institute of Fundamental Research. (Bottom) Location of Indian stations for the International Years of the Quiet Sun.

of this is the Indian government's approval, in principle, of a $7-million program to set up a Space Technology Center on Veli Hill near Thumba and to build an all-Indian rocket capable of carrying perhaps 50 kilograms to heights of 400 or 500 kilometers. The Indians chose to manufacture foreign rockets first to gain experience. This is why at least 12, and perhaps as many as 24, Centaures will be built in Bombay.

In contrast to the first payloads, most of the 20 scheduled to be flown during the year ending 31 March 1966 will be constructed in India. So P. D. Bhavsar of the Physical Research Laboratory will be building most of the dozen experiments planned for studying the ionospheric winds.

Satyaprakash (who lacks a western-style first name) is developing a resonance probe of electron density for use in 1965–66 or later. Unlike the mechanical American model on which it is based, Satyaprakash's instrument will be all-electronic. Like the Langmuir probe sent aloft with the first French Centaure sodium-vapor rocket on 29 April, the new instrument will be used for measuring electron densities in the ionosphere, particularly in the so-called "sporadic E layer," and will relate changes in this density to the behavior of the electrojet.

In future, such electron-density experiments will usually fly magnetometer probes supervised by T. S. G. Sastry, Cahill's main collaborator in Ahmedabad. Sastry sees two main difficulties with the present magnetometer probes of the electrojet. One is that the rockets now used are too large and cannot be fired quickly in response to sudden changes in magnetometer readings on the ground. The other is that the interval between measurements by the instruments is so long—700 milliseconds—that the entire electrojet (no more than 1.5 kilometers thick) could be missed.

To study the ionosphere, A. P. Mitra and Y. V. Somayajulu of the National Physical Laboratory in New Delhi have developed riometers, DC probes, and Lyman-alpha probes.

Although such laboratories as the ionospheric group of the National Physical Laboratory, the Astrophysical Observatory at Kodaikanal in southern India, and the Tata Institute carry out vital parts of the Indian program, the scientific heart of the Indian space effort is at the Physical Research Laboratory in Ahmedabad.

One reason for this is that Sarabhai, the chairman of India's national committee on space research (INCOSPAR), became director of the Physical Research Laboratory in June, succeeding K. R. Ramanathan, who retired. Ramanathan, an expert on atmospheric ozone and a former president of the International Union of Geodesy and Geophysics, had directed the Laboratory since its inception in the late 1940's.

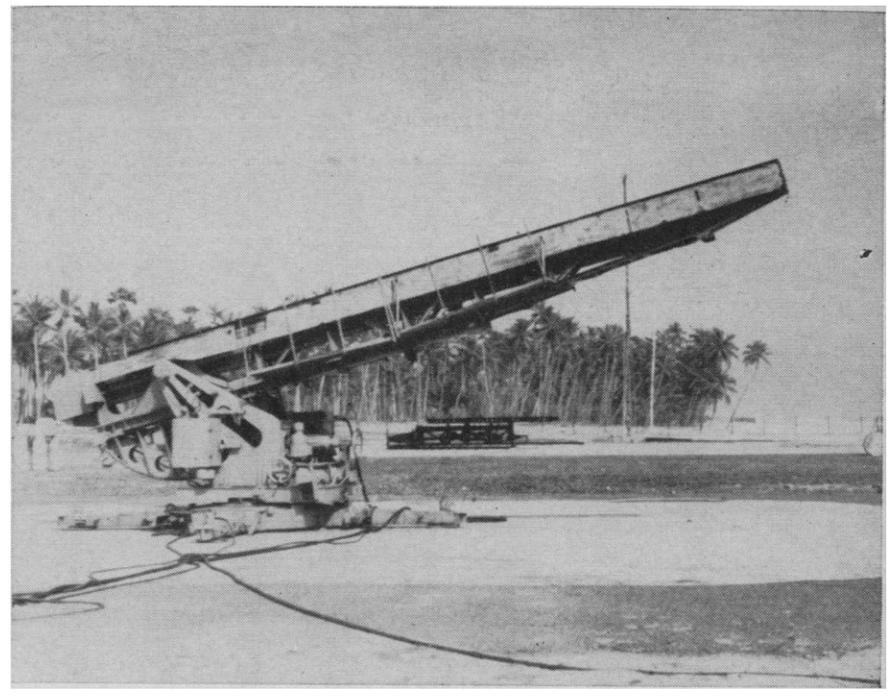
Both Sarabhai and Ramanathan have led important programs of ground-based research—programs which expanded under the stimulus of the International Geophysical Year and the International Years of the Quiet Sun.

Using counters and monitors at several sites in India and at Chacaltaya in Bolivia, Sarabhai and his colleagues R. P. Kane, N. W. Nerurkar, G. L. Pai, S. P. Pandya, U. R. Rao, and others study cosmic rays as they are influenced by the sun's magnetic field.

Working with Ramanathan on studies of ozone are G. M. Shah and P. D. Angreji; R. G. Rastogi, S. S. Dagaonkar, and J. L. Shirke are making measurements of the ionosphere from the ground. At Ahmedabad and Mount Abu, the nearest hill station, P. V. Kulkarni is observing airglow from atmospheric sodium at a wavelength of 5890 angstroms and from oxygen at wavelengths of 5577 and 6300 angstroms.

The Physical Research Laboratory does not limit itself to research. Some 20 graduate students are working for degrees from Indian universities. They do research with 18 faculty members, six research associates, and ten research assistants. Laboratory staff members also take part in a large program to improve science teaching in the Ahmedabad area. The program began in 1963 and covers biology, chemistry, mathematics, and physics.

Western observers may be surprised to find a space research program, albeit small and focused on the electrojet, in a poor country—even one as advanced as India, where a large atomic energy program provides financial, intellectual, and administrative support. But the program is not very expensive: $1 million a year is now being spent on it, and perhaps $3 million a year will be spent in the near future. And the research is a natural outgrowth of the rapidly expanding geophysical studies which are being made in Indian universities, and which, one could argue, Indian universities must pursue in order to avoid isolation and stagnation.



(Foreground) Launcher for French Centaure rockets and (background) launcher for Nike Apache rockets, located at the Thumba rocket base, India.

For a participant in the Indian space program, however, there may be an odd mixture of cultural heritages, as a few facts about Sarabhai will show. Sarabhai's family runs one of the largest textile mills in Ahmedabad, India's textile center. Like many Indian industrial families, the Sarabhais were involved with Gandhi and the Congress Party during the intensified struggle for independence after the Amritsar massacre of 1919. Gandhi set up his first Indian *ashram* or community in Ahmedabad in his native Gujarat after returning from South Africa, and once led a strike against the Sarabhai mill (a lady of the Sarabhai family had already joined Gandhi's following). As a young student in 1930, Sarabhai himself was one of Gandhi's followers. But Sarabhai had already decided on science as a career. He studied at Cambridge in the late 1930's, at Bangalore during World War II, and at Cambridge again after the war. On his return to India, Sarabhai dircted the laboratories of the Ahmedabad Textile Industry's Research Association, across the road from the Physical Research Laboratory. Sarabhai is married to one of the leading classical dancers of India.

—VICTOR K. MCELHENY